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Effects of Aldrin on Young Pheasants Under Semi-Natural Conditions

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EFFECTS OF ALDRIN ON YOUNG PHEASANTS UNDER SEMI-NATURAL CONDITIONS

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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RET

ABSTRACT

Effects of aldrin on young pheasants were studied under semi-natural conditions in four one-acre enclosures during the summer of 1968. The center two-thirds of each plot was planted in corn; remaining peripheral cover was maintained in smooth brome and alfalfa. Prior to planting, center portions of two plots were sprayed with 2 pounds of aldrin per acre on May 20, while remaining plots served as controls.

On June 12, four family units consisting of two broody pheasant hens and two bantam hens with 15 three-day-old chicks each were confined in plots. Hens and broods were given free run 10 days later. Beginning with birds 19 days of age, two to three were collected weekly from each plot for food habits and insecticide analysis. Several birds found dead were also analyzed.

Whole-body analysis of aldrin and dieldrin residues for 47 treated birds from 16 to 92 days of age and 12 control birds from 19 to 68 days of age was completed with electron capture gas chromatography. Wet-weight concentrations of aldrin and dieldrin combined ranged from 0.06 - 0.10 and averaged 0.07 ppm for control birds, and 0.11 - 1.26 and 0.38 ppm for treated birds. No relationship was found between length of exposure and tissue concentrations. However, highest concentrations for both treated plots occurred in tissue of birds 61 days of age. Analysis of

nine feather samples suggested uropygial secretions as one source of dieldrin residues in feathers.

Despite close association with treated habitat and below normal weights, no mortality could be attributed to the insecticide application. Residue concentrations were comparable to residues reported for wild pheasants in South Dakota. However, extrapolation of these findings to wild conditions is difficult.

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INTRODUCTION

Many studies have attempted to determine direct or indirect effects of various chlorinated hydrocarbon insecticides upon ring-necked pheasants (*Phasianus colchicus*). They have often involved laboratory experiments in which chemicals were administered to adult birds (and occasionally juveniles) via food and gelatin capsules to determine such aspects as acute and chronic toxicity. Possible effects on reproductive physiology, egg hatchability, and survival and development of young have also been studied under laboratory conditions (DeWitt 1956, Genelly and Rudd 1956).

Another approach to assessing possible effects of insecticides on pheasants would be to create semi-natural conditions under which pheasants were raised in an area consisting of a large proportion of treated soil surrounded by untreated habitat. This thesis discusses such a study using aldrin in one-acre enclosures.

Young pheasants were chosen for study since their diet is highly insectivorous early in life (Dalke 1935, Ferrel et al. 1949), and young birds are more susceptible to insecticides than adults (Arant 1952, Sherman and Rosenberg 1953).

Aldrin is one of the most widely used chlorinated hydrocarbon insecticides in the United States. It has received wide use as a soil insecticide throughout cornbelt states for control of some 25 to 30 insect species including corn rootworms, cutworms, and wireworms (Gunderson 1968). With the appearance of resistant strains of corn rootworms in South Dakota in 1962, aldrin has since been recommended primarily for control of cutworms and wireworms (Kantack et al. 1967). During 1966 approximately 58% of the corn acreage treated with an insecticide in the cornbelt states received an application of aldrin. This represented 23% of the total corn acreage (Fitzsimmons 1968).

Prior to 1964, both soil and foliar applications were made with aldrin and its epoxide, dieldrin. However, in 1964 foliar applications were discontinued by Federal law. These chemicals now are approved only for usage in crops without tuberous root systems (U.S. Dept. Agr. 1965). In South Dakota aldrin is presently approved only for soil treatment of corn (Kantack and Berndt 1968).

This study was initiated to: (1) determine feasibility of and techniques required to carry out a large enclosure insecticide study, (2) determine effects of a recommended level of a widely-used insecticide upon pheasant chicks, (3) determine residue levels that occur in pheasant tissue under such conditions, and (4) relate these findings to wild conditions.

DESCRIPTION OF STUDY AREA

The study area, 1 mile north of Brookings, South Dakota, was vegetated with a mixture of smooth brome (*Bromus inermis*) and alfalfa (*Medicago sativa*) for the past seven years. Prior to this time swine were pastured on this area 3 months each year. Hay mowing was terminated in June 1967 to encourage a dense growth of alfalfa and brome grass for brood cover. Brood cover was taller and denser in two plots as a result of increased moisture conditions caused by an adjacent shelterbelt. The entire enclosure was surrounded by a 4- to 6-foot strip of uncut smooth brome and alfalfa to provide additional insect cover. Plants found within enclosures are listed in Appendix A.

Soils of the area are chernozems with a silty clay loam texture that developed under tall grass vegetation (Westin et al. 1959). Prior to this study no insecticide application had been made on the area for at least 10 years.

Climate of Brookings County is continental with large seasonal and even daily temperature fluctuations being common. Eighty percent of the average seasonal precipitation of 20.37 inches falls during the growing season. Relative humidity in summer averages 85% in early morning and 55% in the afternoon. Summer prevailing winds are southerly and average 10 miles per hour (Spuhler 1966).

METHODS AND MATERIALS

Enclosures, Spraying and Planting

The rectangular study area was subdivided into four quarters (1.04 acres each) with treated plots (numbers 1 and 3) at opposite corners. The enclosures were created by building an 8-foot fence using a 2-foot strip of 1-inch mesh chicken wire along the base and 2-inch mesh above. Half of the bottom 2-foot strip was buried.

The center two-thirds of each plot was planted in corn on May 21; remaining peripheral area was maintained in smooth brome and alfalfa. Center portions of plots 1 and 3 were sprayed with an emulsifiable concentrate of aldrin at a locally recommended rate of 2 pounds per acre on May 20, 1968. As recommended (Kantack and Berndt 1968) this treatment was immediately disced into the soil to prevent loss of insecticide. Remaining two plots served as controls. Spraying and planting dates thus approximated those suggested for east-central South Dakota (U.S. Dept. Agr. 1968).

Corn was cultivated on June 7, prior to brood establishment. A second cultivation on July 8, using a small garden roto-tiller was unsuccessful and by late summer corn was densely vegetated with buffalo bur (*Solanum rostratum*), lambsquarters (*Chenopodium album*), common purslane (*Portulaca oleracea*), green foxtail

(*Setaria viridis*), pigeon grass (*S. glauca*), summer cypress (*Kochia scoparia*), and alfalfa.

Adoption Experiments and Brood Establishment

Adoption experiments were conducted during the spring of 1968 to determine feasibility of using game farm or wild pheasant hens to adopt and brood pheasant chicks within large outdoor enclosures. Thirty-one game farm and six wild pheasants were confined in small triangular cages (12 x 18 x 12 inches high), and light was regulated to induce laying. During the adoption experiment, hens which had been laying were placed in darkened coops (each 26 x 36 x 18 inches high) and given several 1- to 5-day-old chicks. Fifteen of these hens, including one wild hen, became broody. Eight were selected for field use and were maintained in a broody condition by leaving them with young pheasants. Remaining hens were considered too excitable for field use.

A total of 16 hens (four per plot) was required, so additional incubating bantam hens were purchased the second week of June. Eight of nine bantam hens known to have raised broods of their own the previous summer became broody when confined with pheasant chicks.

During the second week of June, hens and their first broods were moved outside to individual rearing shelters (Fig. 1).

Figure 1. Shelters and nursery pens used to confine hens and broods prior to release.

Figure 2. Fifteen-foot runways allowed exposure to cultivated areas.

A bottomless 2 x 3 foot nursery pen made of a wooden frame covered with two pieces of overlapped 1-inch mesh chicken wire was attached to each shelter. It was later necessary to attach an additional strip of window screening to prevent escape.

The 16 broody hens were randomly divided among four enclosures so as to have two pheasant and two bantam hens per plot. Primary and secondary feathers were clipped on all hens to prevent escape. On June 10, shelters and broods were moved to their respective plots and placed on opposite sides of the fields in peripheral cover.

Two-day-old chicks (purchased from Wild Wings of Oneka, Hugo, Minn.) were obtained June 11. All chicks were immediately pinioned and tagged with No. 3, colored, aluminum, patagial wing bands (National Band and Tag Co., Newport, Ky.). The following morning chicks were separated into groups of 15 and exchanged for older chicks which had been with each hen. Broods were thus established on June 12 to coincide with the average hatching peak for South Dakota.

Confinement of broods would have made it possible to chase broods into shelter in the event of a severe weather warning. At 7 days of age chicks were allowed to run in an additional 2 x 15 foot chicken wire runway anchored to the ground and extended approximately 7 feet into the plowed portion of each plot (Fig. 2). Birds within treated plots (hereafter referred to as treated birds) were therefore potentially exposed to insecticide treated soil at 7 days of age, but may have eaten insects carrying residues prior to this time.

Hens and 10-day-old broods were given free run of enclosures June 20. Food was removed at this time. Birds were collected for analysis at weekly intervals beginning with birds 19 days of age. Several additional birds found dead were also analyzed. Prior to freezing, collected birds were weighed, sexed, and crops and gizzards were removed for food habits analysis.

Tissue Residue Analysis

Forty-seven treated birds (21 from plot 1, 26 from plot 3) and 12 control birds (six from each control plot) were analyzed for aldrin and dieldrin residues. Sufficient quantities of DDE were also present to permit quantitative calculations. Whole-body analysis was employed with feathers, crops and gizzards removed prior to grinding. Frozen samples were put through a meat grinder until a homogenous sample was obtained. These ground samples were then refrozen in plastic bags washed in a strong alkaline detergent followed by rinses in distilled water, acetone and hexane. From each frozen sample six subsamples were removed, combined into a 1-g (wet-weight basis) sample and analyzed using florisil column cleanup and electron capture gas chromatography (ECGC) procedures as described by Stemp et al. (1964)

and employed more recently by Greichus et al. (1968) for pheasant tissues.

The instrument used for ECGC was a Wilkens Aerograph HY-FI, model 600 equipped with an electron-capture detector cell with a 250-millicurie tritium source. Two 1/8-inch o.d. X 5-foot Pyrex columns (one packed with 5% Dow-11 silicone, the other with 2% QF-1 silicone on 60 to 80-mesh, HMDS-treated Chromosorb W) were used for qualitative verification on all samples. Quantitative calculations were made from the Dow-11 column. Thin-layer chromatography as described by Breidenbach et al. (1964) was employed as further qualitative verification of four tissue and two feather samples.

To determine efficiency of extraction, aldrin and dieldrin were added to control tissue. By knowing amounts added and by calculating amounts recovered after these procedures, it was possible to determine percent recovery. Recovery values of 96% and 98% for aldrin and dieldrin were used in quantitative calculations.

Feather Residue Analysis

Feathers were analyzed from six treated and three control birds which had been analyzed for tissue residues. Oily basal portions of feathers were discarded. Feathers from all parts of the body were combined and cut into fine pieces with scissors. One-gram samples of this material were added to 30 ml petroleum ether and mixed for 5 minutes in a high speed mixer. Samples were filtered, evaporated to 10 ml and poured over a florisil column. ECGC procedures were the same as used with body tissue. Percentage recovery for this procedure was 83% for aldrin and 67% for dieldrin.

Feed Residues

A mixture of pheasant chick-starter (Zip Feed Mills, Sioux Falls, S. Dak.) and cracked corn used to feed birds prior to release and to supplement their diet following release was analyzed using an extraction procedure described by Mills et al. (1963). Homogenous 50-g samples were obtained using a high speed "micro-mill" (Chemical Rubber Co., Cleveland, Ohio). Samples were purified and analyzed by the same methods used for tissue.

Soil Residue Analysis

Soil samples were collected from cultivated portions of plots four times during the summer of 1968 as follows: May 12, June 17, September 3, and October 26. The first collection, made 8 days prior to spraying, consisted of two samples from each of the four plots. A second collection was made 28 days after spraying to coincide with release of all broods, and consisted of three samples from each of the two sprayed plots. Single composite samples consisting of six subsamples each were collected from all plots at 106 and 160 days following spraying with aldrin. Samples were taken from the upper 4 inches of soil.

Samples from the first three collections were analyzed by Spectran Laboratories Inc., Denver, Colo. Analyses were made on 100-g samples using acetone solvent extraction, magnesium oxide-celite column cleanup, followed by ECGC analysis using a Varian Aerograph model 204B with Dow-11 and QF-1 columns.

Samples of October 26, were analyzed by this investigator following procedures outlined by Shell Development Co. (1964) using a hexane/propanol-2 extraction solvent and florisil columns topped with 1/2-inch of anhydrous sodium sulfate. Thereafter, cleanup procedures and ECGC determinations were identical to those employed throughout the study.

RESULTS AND DISCUSSION

Food Habits

Since ingestion of foods contaminated with insecticides is a major source of insecticide residues in animal tissues (Rudd and Genelly 1955), it is important that food habits be investigated. Crop contents from 84 birds from 2 to 12 weeks of age were analyzed to compare proportions of animal and plant material eaten in this study to those found from birds collected under wild conditions. Contents were analyzed on a percentage-by-volume basis using volumetric test tubes calibrated to 0.1 ml (Appendix B). Quantities less than 0.1 ml were recorded as trace amounts. No comparisons were made between control and treated groups due to the small sample size for each weekly interval.

The few studies which exist on food habits of juvenile pheasants indicate that animal matter (primarily insects) makes up the bulk of the diet shortly after hatching and gradually decreases through summer until 12 to 13 weeks of age at which time their diet is similar to adults (Dalke 1937, Ferrel et al. 1949, Loughrey 1951, and Trautman 1952).

Pheasant chicks on Pelee Island relied almost entirely on animal matter for the first 3 weeks of life (Loughrey 1951). Using percentage-by-weight methods, Dalke (1937) found that 90% of the diet for 1-week-old birds was animal matter, and averaged 64% for birds 2 and 3 weeks of age. Ferrel's (1949) data were analyzed on a percentage-by-volume basis combining material from crops and gizzards. Animal matter exceeded 40% of the total volume in all age groups through 9 weeks of age. However, inclusion of gizzard contents biased results upwards for insect matter due to retention of hard insect body parts (Jenson and Korschgen 1947).

First birds collected in this study were 3 weeks of age. Two-week-old birds listed in Appendix B were found dead. Three-week-old birds were collected between 9:20 and 9:53 A.M.; 4-week-old birds were taken between 7:50 and 9:25 A.M. Thereafter, all birds were collected during late afternoon. Fourteen of 29 crops from birds 2 to 4 weeks of age were empty; nine of these were from birds found dead. Only five crops from birds taken during this period contained 0.1 ml or more of either plant or animal matter. Only about 10% of juvenile birds collected by Dalke (1937) had empty crops between 5 and 9 A.M., and none were empty between 9 and 12 A.M.

This large proportion of empty or near empty crops prevented conclusions regarding food habits of birds 2 to 4 weeks of age. However, visual estimates of animal matter in 41 gizzards and field observations indicated that some chicks were obtaining large quantities of insects, primarily ants and beetles, during this period.

For birds 5 through 10 weeks of age animal matter made up only 20% of the diet. Since both sample size and volumes of food were small, considerable error was probably involved. This figure was obtained by averaging contents from only those birds containing 0.1 ml of animal and plant material in their crops. If trace amounts of animal matter had been included, this percentage would be lower.

Trautman (1952) found animal matter averaged 35% of the diet during July and August. For birds 5 through 10 weeks of age Ferrel et al. (1949) found 49% of the diet to be animal matter. However, approximately 60% of his sample material was gizzard contents. It is therefore concluded that birds in this study were consuming less animal matter than would normally be expected under wild conditions.

Based on frequency of occurrence in crop contents the five most important items eaten (in order of importance) were leaves and flowers of alfalfa, bindweed seeds (Polygonum convolvulus), green foxtail seeds, leaves of lambsquarters, and fruits of shepard's purse (Capsella bursa-pastoris). Ants and a large variety of beetles were the most important insects eaten. Other important animals eaten were aphids, grasshoppers, spiders, plant bugs, crickets, planthoppers, flies, damsel bugs, and moths.

Seeds did not appear in crop contents until approximately 4 weeks of age. Prior to this time, plant items which occurred most often were leaves of alfalfa, lambsquarters, and common purslane, and fruiting heads of peppergrass (Lepidium densiflorum), shephard's purse and field-penny-cress (Thlaspi arvense). Alfalfa leaves and flowers were important throughout the study. Bindweed and foxtail seeds first occurred in more than trace amounts in crops from birds 4 and 5 weeks of age, respectively. These seeds continued to increase in importance and were dominate items in crops of older birds. Bantam and pheasant hens were most often observed eating alfalfa leaves and flowers and bindweed seeds.

Weight and Mortality Information

Weights of birds are often a good indication of general condition (Westerskov 1957), and body condition, as reflected by weight, may have direct implications on potential effects of insecticides. In laboratory studies involving heptachlor, Stickel et al. (1965) found that most underweight woodcocks (Philohela minor) died at levels of heptachlor well below those at which nearly all birds in a normal-weight group lived.

Growth curves have been determined for captive pheasants by Kirkpatrick (1944), Wight (1945), Buss (1946), and Trautman (1950) and for wild pheasants by Stokes (1954). Stokes compared growth curves for his data on wild juvenile cocks from Pelee Island, Ontario, with those of the above investigators and found them very similar. Weight data from this study were compared to information collected by Stokes since his data was for wild pheasants and correlated closely with other studies.

A comparison of mean weights of male and female pheasants of various ages collected in this study to those of birds collected by Stokes is presented in Table 1. Mean weights averaged 48% below mean weights found by Stokes. Since sample sizes were small and development of vegetative cover varied among plots, differences were considered small when weights were compared between plots, between males and females, and between treated and control groups.

Mortality and abnormally low weights found in this study were attributed to a combination of the following factors: (1) an abrupt change from a provided diet to one which broods could obtain on their own, (2) poor weather which resulted in lowered availability of insects and less time spent searching for food, and (3) insufficient quantities of protein-rich insect foods due partly to high concentrations of birds.

Chicks had been provided a diet of chick-starter mash from hatching until release at 10 days of age. It was hoped they would become accustomed to searching for a portion of their diet while confined. However, several days after release it became evident that difficulty was being encountered in obtaining ample food. Findings of several dead chicks together with persistent crying of many other chicks prompted the use of supplemental feed. Beginning on June 23 commercial feed mixed with corn was thrown to located broods every 2 to 3 days until July 10. Game breeders who have raised pheasants under an "open range system"

Table 1. Mean weights (g) of 38 male and 36 female juvenile pheasants of various ages compared to mean weights of wild birds from Pelee Island, Ontario.* (sample size in parentheses.)

	Males			Females		
Age (Weeks)	Mean Weight This Study	Mean Weight Pelee Island	Percent Departure	Mean Weight This Study	Mean Weight Pelee Island	Percent Departure
3	57 (6)	88 (38)	35%	47 (6)	88 (38)	47%
4	75 (6)	155 (20)	52%	70 (6)	155 (20)	55%
5	74 (4)	220 (111)	66%	83 (4)	209 (89)	60%
6	122 (4)	302 (377)	60%	110 (4)	262 (254)	58%
7	192 (5)	398 (491)	52%	153 (3)	336 (369)	55%
8	240 (6)	496 (371)	52%	178 (1)	400 (291)	56%
9	321 (2)	585 (232)	45%	285 (5)	480 (232)	41%
10	387 (3)	700 (118)	45%	343 (4)	552 (96)	38%
11	--- -	791 (75)	--	489 (2)	646 (49)	24%
12	531 (1)	909 (27)	42%	381 (1)	684 (21)	44%
13	549 (1)	925 (6)	41%			
Mean Percent Deviation			49%			48%

* Data adapted from Stokes (1954:109 and 111) for birds collected in 1950.

similar to that employed here, recommend birds be continually provided with food after release (Holm 1946).

Animal matter is an important source of protein for growing pheasants (Dalke 1935). Without adequate protein levels, body development is retarded. Nutritional studies on game farm pheasant chicks indicated maximum rate of growth can be obtained on a diet containing 30% protein. Lower, but satisfactory, growth rates were obtained on 21, 24, and 27% protein levels. Growth was significantly retarded below these levels. Combined weights of males and females at 8 weeks of age for birds on a 15% protein diet was approximately 38% below average weights for birds on a 30% level (Norris et al. 1936). Studies by Dale and DeWitt (1958) indicated weights of birds on diets containing 15 to 18% protein were approximately 50% lower than pheasant chicks on a 28% level.

Average protein content of alfalfa, green foxtail, and pigeon grass (plant foods eaten in this study) is approximately 19% compared to 51% for a combination of ants, beetles, caterpillars, grasshoppers and other insects (Korschgen 1964).

A combination of wet, cool weather with the resulting lowered availability of insects was believed to have caused heavy losses for 2 1/2-weeks following release of broods. Rain occurred during 11 days of this period (Spuhler 1968), and many of the 51 birds unaccounted for presumably also died during this period.

Table 2 indicates the distribution of mortality of 99 birds found dead during the study. Many chicks found dead between June 12 - 18 were believed to have been accidently stepped on by excited hens. This was observed with pheasant hens on several occasions. Bantam hens were less excitable and fewer of their chicks died from this cause. Many chicks were killed by a severe hail storm on June 22. One brood of 12 chicks was destroyed after the pheasant hen was apparently hit by hail and left the brood. Most of the bantam hens continued to use shelters for roosting at night, and as a result, fewer chicks were killed during this storm; however, several chicks from bantam broods were found outside the shelter entrances the following morning. They apparently fled the shelter and were instantly killed.

Weather conditions improved during the second week of July and supplemental feeding was discontinued on July 10, except as a means of luring birds for collection purposes. No birds were found dead after July 16.

Soil Residues

Aldrin is one of the least persistent chlorinated hydrocarbon insecticides and readily converts to dieldrin in soil (Gannon and Bigger 1958), on plants (Gannon and Decker 1958), and within animal tissues (Bann et al 1956). Dieldrin is more stable and small quantities may persist in soil for up to 25 years (Edwards 1964).

Table 2. Distribution of mortality between age intervals for 99 pheasant chicks found dead between June 12 and July 16, 1968.

Age (days) Intervals	Dates	No. Dead Chicks: Treated Plot 1	Treated Plot 3	Control Plot 2	Control Plot 4	Totals
3-9	6/12-6/18	10	8	7	12	37
10-16	6/19-6/25	1	5	15	3	24
17-23	6/26-7/2	7	9	3	10	29
24-30	7/3 -7/2	1	1	0	2	4
31-37	7/10-7/16	0	2	1	2	5
Plot Totals		19	25	26	29	99

Concentrations of aldrin and dieldrin from soil collected prior to and after spraying are presented in Table 3. Aldrin and dieldrin were the only chlorinated hydrocarbon insecticides present above experimental detectable limits prior to spraying.

Aldrin concentrations for June 17 are considered highly questionable since residues present immediately after spraying should approximate 1 ppm when 2 pounds per acre are used (Decker et al. 1965). In addition, residues would be highest immediately after spraying and would gradually decline with time. Data in Table 3 indicate that residues of aldrin were lower at 28 than at 106 days after spraying. Concentrations of aldrin and dieldrin at 106 days after spraying were comparable to data presented by Decker et al. (1965).

Composite samples were not taken during first and second collections, therefore, minimum and maximum values varied considerably for different locations. Composite samples were taken for third and fourth collection dates and results are considered more representative than previous samples.

In Illinois, highest concentrations of dieldrin occurred between 60 and 120 days following treatment with aldrin, and ranged between 0.085 and 0.125 ppm where 1.5 pounds had been applied (Decker et al. 1965). Too few collection dates were used in this study to determine a dieldrin peak. At 106 days following spraying 0.11 ppm were present. Based on data from

Table 3. Mean concentrations of aldrin and dieldrin (ppm) for soil collected from treated and control plots prior to and after spraying of plots 1 and 3 with aldrin.*

Collection Date	Plot	Aldrin	Dieldrin	Plot	Aldrin	Dieldrin
May 12 (8 days prior	1	0.004	0.005	2	0.002	0.005
to spraying)	3	0.001	0.006	4	0.001	0.010
June 17 (28 days after	1	0.083	0.014	**		
spraying)	3	0.087	0.041			
September 3 (106 days	1	0.22	0.11	2	0.09	0.06
after spraying)	3	0.14	0.11	4	0.01	0.002
October 26 (160 days	1	0.014	0.028	2	0.002	0.001
after spraying)	3	0.014	0.028	4	0.002	0.004

* Samples from the first three collection dates were analyzed by Spectran Laboratories Inc. Denver, Colo.; the last sample was analyzed by this investigator.

** Sample not collected for control plots on June 17.

Illinois it would appear that the peak was probably reached sometime prior to this time, since values would be expected to be somewhat above 0.125 ppm where 2 pound treatments are employed.

Residues in soil from control plots were nearly the same at 160 days after spraying as pre-spraying values. Samples at 106 days after spraying indicated a slight increase of residues in control plots. This increase was presumably due to drift of insecticide during and after spraying.

Feather Residues

Feather residues result from at least two sources: (1) direct contact with contaminated materials (e.g. dusting in treated soil) and (2) indirectly through secretions produced by the uropygial (preening or oil) gland. These secretions are high in fatty acids, fats, and waxes (Elder 1954). Since chlorinated hydrocarbons are associated with fatty materials (Bann et al. 1956), it seems conceivable that some residues were eliminated via these secretions. Dindal and Peterle (1968) found uropygial glands of mallards (*Anas platyrhynchos*) and lesser scaup (*Aythya affinis*) contained highest residues of DDT and its metabolites of any tissue analyzed.

Concentrations of aldrin and dieldrin present in nine feather samples were compared with tissue residues (Table 4).

Table 4. Concentrations (ppm) of aldrin (A) and dieldrin (D) in feather samples from six treated and three control juvenile pheasants compared to whole body tissue concentrations.

Group	Bird	Age (Days)	Feathers			Tissue		
			A	D	A + D	A	D	A + D
Treated	Y-55	19	0.02	0.31	0.33	0.02	0.09	0.11
	Y- 1	19	0.03	0.53	0.56	0.02	0.20	0.22
	Y-32	47	0.10	0.23	0.33	0.03	0.09	0.12
	Y-49	47	0.04	0.32	0.36	0.04	0.17	0.21
	Y-23	82	0.05	0.42	0.47	0.02	0.53	0.55
	Y-29	82	0.02	0.19	0.21	0.03	0.46	0.49
Control	W-24	19	0.02	0.14	0.16	0.02	0.04	0.06
	W-51	47	0.03	0.32	0.35	0.02	0.08	0.10
	W-16	68	0.02	0.13	0.15	0.02	0.04	0.06

Feathers of all three control and four of six treated birds contained higher dieldrin residues than tissues. Excluding the two oldest treated birds, those birds with highest dieldrin tissue residues also had highest dieldrin concentrations in their feathers.

Cultivated portions of all plots were used extensively for dusting. If direct contact with contaminated soil was a primary source of aldrin residues in feathers, younger birds from treated plots should have contained higher aldrin concentrations in feathers. Limited data do not indicate this relationship. Aldrin residues were similar for both tissues and feathers and for control and treated groups. On the other hand, average dieldrin concentrations for feathers of treated birds were higher than in control birds. Based on this limited data, it is suggested uropygial secretions are one source of dieldrin residues in feathers. This has also been suggested by Dindal and Peterle (1967).

Tissue Residues

Concentrations (ppm wet weight) for aldrin, dieldrin, aldrin plus dieldrin, and DDE are presented in Table 5. Heptachlor epoxide, DDD, and DDT were also found in many tissue samples in amounts less than 0.01 ppm. Concentrations of DDE were not significantly different ($P > 0.05$) between or within treated and control groups and averaged 0.12 ppm (Table 6).

Table 5. Concentrations (ppm wet weight) of aldrin, dieldrin, and DDE from 47 treated and 12 control birds. (Whole-body analysis with feathers, crops and gizzards removed.)

Group	Bird	Sex	Age (Days)	Aldrin	Dieldrin	Aldrin + Dieldrin	DDE
Controls (Plot 2)	W-24	M	19	0.02	0.04	0.06	0.10
	W-21	M	26	0.02	0.04	0.06	0.08
	W-25	M	40	0.02	0.05	0.07	0.10
	W-51	F	47	0.02	0.08	0.10	0.10
	W-10	F	61	0.02	0.05	0.07	0.18
	W-16	M	68	0.02	0.04	0.06	0.09
Controls (Plot 4)	B-54	M	19	0.02	0.06	0.08	0.18
	B-65	M	26	0.02	0.07	0.09	0.16
	B-36	F	33	0.01	0.06	0.07	0.18
	*B-30	M	33	0.02	0.04	0.06	0.14
	B-19	F	40	0.02	0.05	0.07	0.11
	B-50	M	55	0.01	0.07	0.08	0.19
Treated (Plot 1)	*R-47	M	18	0.02	0.18	0.20	0.10
	*R-19	F	18	0.03	0.28	0.31	0.20
	R-42	F	19	0.01	0.24	0.25	0.14
	R-38	F	19	0.03	0.24	0.27	0.09

* Found dead during the study.

Table 5. (Continued).

Group	Bird	Sex	Age (Days)	Aldrin	Dieldrin	Aldrin + Dieldrin	DDE
	R-22	M	19	0.02	0.70	0.72	0.06
	*R- 7	M	21	0.02	0.29	0.31	0.17
	R-23	F	26	0.03	0.52	0.55	0.16
	R-32	M	26	0.03	0.34	0.37	0.11
	R-35	F	26	0.02	0.28	0.30	0.14
	*R-16	F	28	0.01	0.34	0.35	0.12
	*R-28	M	28	0.02	0.19	0.21	0.15
	*R-18	F	28	0.02	0.37	0.39	0.20
	R-14	M	33	0.02	0.48	0.50	0.07
	R-33	F	33	0.02	0.24	0.26	0.08
	R-43	M	40	0.05	0.36	0.41	0.12
	R-55	F	40	0.01	0.38	0.39	0.13
	R-12	M	47	0.03	0.18	0.21	0.10
	R-15	M	47	0.03	0.37	0.40	0.15
	R-39	M	55	0.02	0.63	0.65	0.11
	R-24	F	61	0.02	0.98	1.00	0.08
	R-45	M	92	0.01	0.11	0.12	0.10
	*Y-19	F	16	0.02	0.15	0.17	0.08
Treated	*Y-60	F	16	0.03	0.15	0.18	0.15
(Plot 3)	Y- 2	F	19	0.02	0.41	0.43	0.11

* Found dead during the study.

Table 5. (Continued).

Group	Bird	Sex	Age (Days)	Aldrin	Dieldrin	Aldrin + Dieldrin	DDE
	Y-55	M	19	0.02	0.09	0.11	0.13
	Y- 1	M	19	0.02	0.20	0.22	0.11
	*Y-64	F	21	0.02	0.43	0.45	0.15
	*Y-59	M	21	0.02	0.12	0.14	0.14
	Y-38	F	22	0.04	0.26	0.30	0.23
	Y-11	F	26	0.02	0.18	0.20	0.10
	Y-43	F	26	0.02	0.39	0.41	0.10
	Y-46	M	26	0.03	0.15	0.18	0.17
	Y- 8	F	33	0.03	0.22	0.25	0.07
	Y-50	F	33	0.02	0.09	0.11	0.08
	*Y-20	M	33	0.08	0.08	0.17	0.13
	Y-58	F	40	0.05	0.22	0.27	0.11
	Y-65	M	40	0.02	0.22	0.24	0.09
	Y-32	M	47	0.03	0.09	0.12	0.08
	Y-49	F	47	0.04	0.17	0.21	0.12
	Y- 9	F	55	0.03	0.15	0.18	0.27
	Y-22	M	55	0.02	0.40	0.42	0.05
	Y-15	F	61	0.03	1.23	1.26	0.11
	Y-34	M	61	0.03	0.75	0.78	0.10
	Y-18	F	68	0.06	1.03	1.09	0.10
	Y-44	F	68	0.01	0.69	0.70	0.13
	Y-23	M	82	0.02	0.53	0.55	0.09
	Y-29	F	82	0.03	0.46	0.49	0.08

* Found dead during the study.

Table 6. Range and mean concentrations (ppm wet weight) of aldrin plus dieldrin and DDE for treated and control birds.

Group	Plot	No. Birds Analyzed	Range in Age (days)	Aldrin + Dieldrin Range	Aldrin + Dieldrin Mean	DDE Range	DDE Mean
Control	2	6	19 - 68	0.06 - 0.10	0.07	0.08-0.18	0.11
	4	6	19 - 55	0.06 - 0.09	0.08	0.11-0.19	0.16
Treated	1	21	18 - 92	0.12 - 1.00	0.39	0.06-0.20	0.12
	3	26	16 - 82	0.11 - 1.26	0.37	0.05-0.27	0.12

Eighty-one percent of birds in both treated plots had aldrin plus dieldrin concentrations between 0.11 and 0.50 ppm (Table 7). When values for all ages were averaged, aldrin plus dieldrin concentrations were significantly different ($P < 0.05$) between control and treated groups. Concentrations were not significantly different ($P > 0.05$) within controls or within treated groups. Concentrations of aldrin and dieldrin combined ranged from 0.06 - 0.10 and averaged 0.07 ppm, for control birds, and 0.11 - 1.26 and 0.38 ppm for treated birds.

Concentrations of aldrin remained fairly constant throughout the study. No direct relationship was found between length of exposure to treated soil and tissue concentrations. However, single highest values of aldrin and dieldrin combined for each of the two sprayed plots occurred in birds 61 days of age. Average aldrin plus dieldrin concentrations for treated birds were 5.4 times higher than average values for control birds. Concentrations of insecticides from tissue of birds found dead were not high and again suggested that birds were not dying from insecticides.

In laboratory studies the route of chemical entry is most often through ingestion of treated food or by gelatin capsules. However, under natural conditions animals can also acquire chemicals by absorption through skin, and absorption of volatile materials through lungs and air sacs (Genelly and Rudd 1956). Other studies have shown that young pheasants obtain insecticides

Table 7. Percent distribution of combined concentrations (ppm wet weight) of aldrin and dieldrin from tissues of 47 treated and 12 control birds ranging in age from 16 - 92 days.

Group	Plot	Range (ppm)			
		0.06-0.10	0.11-0.50	0.51-1.00	>1.00
Treated	1	0	81	19	0
	3	0	81	11	8
Control	2	100	0	0	0
	4	100	0	0	0

through eggs produced by hens receiving insecticides (DeWitt 1956, Baxter et al. 1969).

Day-old chicks were not analyzed to determine residues present (via the eggs) prior to exposure to treated fields. Part of the aldrin, dieldrin, and DDE residues present in both treated and control birds presumably came from supplemental feed found to contain 0.002 ppm aldrin, 0.004 ppm dieldrin and 0.003 ppm DDE. Residues in control birds may also have come from residue-carrying insects from adjacent treated plots or from outside the study area.

Several studies have shown that severe pheasant mortality may result where aldrin or dieldrin were used. Labisky and Lutz (1967) reported on the effects of a single, solid-block, aerial application of 2 pounds per acre of granular aldrin for control of Japanese beetles (Popillia japonica) over several areas ranging from 9,838 to 29,880 acres. Estimated mortality of 25 to 50% was reported for one area within 1 month after treatment. Regarding mortality of young pheasants, Labisky and Lutz (1967:23) concluded, "Solid-block applications of high-level dosages of aldrin (1 1/2 - 3 lb. per acre) to land areas during the hatching and brooding periods of pheasants in summer would likely result in catastrophic losses of young pheasants."

Scott et al. (1959) studied effects of another solid-block application of 3 pounds of aldrin per acre. Most losses occurred during the week following treatment. Resident populations of several bird species including pheasants were "virtually eliminated."

Clawson and Baker (1959) reported an aerial liquid application of dieldrin equivalent to approximately 1.56 pounds per acre over a large area resulted in death of nearly all resident bobwhite quail (Colinus virginianus).

The above studies have two factors in common: (1) extensive areas of land were treated, and (2) most of the insecticide remained unincorporated on top of the soil and on vegetation where sprays were used creating high surface residues throughout virtually all of the available cover. Under such conditions hazards are apparently great to ground feeding birds.

In the present study only a portion of the habitat was treated, and liquid application was immediately incorporated into soil thereby reducing surface residues. Birds in treated plots were able to feed in both treated areas and untreated peripheral cover. In addition, to coincide brood establishment with peak hatching dates of wild broods, they were not exposed to treated soil until nearly a month after spraying. Earlier hatched broods under wild conditions might therefore be more susceptible. Also, dieldrin and aldrin were the only insecticides present in soil in amounts greater than 0.001 ppm. Under natural conditions birds may be exposed to a variety of insecticides, and there is some indication that insecticides in combination may be more toxic than one alone (Chemical and Engineering News 1966, Ferguson and Bingham 1966).

Delayed use of cultivated sprayed areas in early spring when soil residues are highest would decrease potential hazards from dermal or respiratory exposure. In the present study broods made little use of cultivated areas early in the study, presumably due to a lack of insects and other foods. During this time, feeding and loafing took place primarily in peripheral cover surrounding corn. As weedy growth developed, birds spent more time in corn, and by late summer it was used almost entirely for feeding and loafing.

Weedy cover was much more developed in this area than in most corn fields of South Dakota and may have encouraged above normal use of the corn area, and therefore, more exposure to insecticides. Hens and chicks dug extensively in all corn plots to obtain ants and to create dusting areas.

Lack of correlation between tissue residues and length of exposure may be attributed to several factors. Since insects contained more residues than plant material grown on aldrin treated soil (Korschgen 1968), individual differences in amounts of insects eaten would relate to quantities of insecticide obtained. Korschgen (1968) has shown that certain insects eaten by wildlife accumulate and store potentially harmful amounts of aldrin and dieldrin. Based on crop and gizzard contents some birds were obtaining a large variety of insects when others were dying, presumably from a lack of adequate food combined with adverse weather.

Individual differences in ability to eliminate insecticides may also have been involved. McEwen et al. (1963) suggested that a bird receiving small quantities of insecticide may be able to eliminate part of this material fast enough to prevent high residue accumulation.

Residues found in this study are comparable to concentrations found in wild pheasants collected in South Dakota. Baxter et al. (1969) reported on analysis of 15 juveniles and 48 adults collected from the highest insecticide use area of the State. Total concentrations of insecticides and their metabolites from brain tissues of juveniles ranged from 0.01 - 2.35 ppm and average 0.13 ppm. Average levels of dieldrin and DDE were 0.10 and 0.05 ppm, respectively. Total residues in eggs collected in this area ranged from no detectable amounts to 1.95 ppm and averaged 0.19 ppm.

Greichus et al. (1968) analyzed fat samples of 48 adult pheasants from South Dakota. Combined levels of DDT, DDD, and DDE averaged 0.37 ppm. Concentrations of DDE average 0.10 ppm. Average and highest values of dieldrin were 0.08 and 1.07 ppm, respectively.

CONCLUSIONS

Although residue concentrations were comparable to those reported for wild pheasants, no mortality could be attributed to the insecticide application. However, several factors should be considered when extrapolating findings of the present study to wild conditions. Birds in this study were consuming commercial feed which was low in insecticides at an age when wild pheasant chicks would normally be consuming almost entirely insects and other animal matter. The desire to confine broods early in the study also prevented direct exposure to treated soil until 7 days of age. Wild pheasants hatched earlier in the spring could be exposed not only at younger ages, but also to higher soil residues. These factors could produce considerable differences if younger pheasants are more susceptible to insecticides as the literature indicates.

Wild birds may initially have higher dieldrin concentrations in their tissues at birth (via the egg) than game farm stock used in this study. DeWitt (1956) has shown minute quantities of insecticide passed through eggs produced by pheasants on a breeding diet containing 2 ppm of aldrin or dieldrin can cause adverse effects on viability and survival of young pheasants. This occurred even when chicks from these eggs were fed an uncontaminated diet. It has also been found that the diet of hen pheasants increases in animal matter in spring (Korschgen 1964), and increased consumption of animal matter could increase amounts of insecticides passed through the egg.

Under natural conditions pheasant broods are also potentially exposed to a variety of insecticides. Too little is known, however, to assess possible effects of combinations of insecticides. In addition, only limited information is available on concentrations of insecticides present in wild juvenile pheasants. Baxter et al. (1969) reported on residues in 15 wild pheasants from 5 to 8 weeks of age, but virtually nothing is known about residues present in younger birds which may have already died and were not available for collection.

It is important to consider several factors which placed treated birds in this study in a more dangerous position. First, broods were very closely associated with treated habitat beginning at 3 days of age. By several weeks after release, treated areas were utilized extensively for dusting, loafing, and feeding. Higher utilization of treated areas could contribute to greater insecticide hazards. The degree of exposure of young pheasants under wild conditions to insecticides is not known. However, many biologists have stressed the importance of fence rows and roadside nesting cover, both of which are often adjacent to treated crop land.

Secondly, if aldrin or dieldrin are similar to heptachlor in being more toxic to birds in poorer condition as reflected by body weight and suggested by Stickel et al. (1965) for woodcocks, birds in treated plots should have been in a more dangerous position than birds in better condition. Despite close association with treated habitat and poor body condition, no mortality could be attributed to the insecticide application.

Before any insecticide can be classified as harmless to pheasants additional information is needed on possible effects sublethal concentrations of insecticides may have on behavioral or other physiological processes. More information is also needed on possible effects of combinations of insecticides.

Techniques employed to obtain broody pheasant hens proved feasible. However, they were time consuming, and only a portion of hens tested became broody and were suitable for field use. Future investigators may therefore wish to use bantam hens or to simply release pheasant hens and roosters within large enclosures and allow natural nesting and brooding to occur. If adequate natural food supplies were available, this approach might eliminate need for supplemental feeding. Larger enclosures, fewer birds, or a reduction in proportion of treated cultivated areas would help to assure ample food supplies.

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APPENDICES

Appendix A. Common and scientific names of plants found within study enclosures.*

Amaranthus retroflexus	Green amaranth
Brassica kaber	Quack grass
Bromus inermis	Smooth brome
Capsella bursa-pastoris	Shepherd's purse
Chenopodium album	Lambsquarters
Convolvulus sepium	Hedge bindweed
Hordeum jubatum	Squirrel-tail grass
Iva xanthifolia	Marsh elder
Kochia scoparia	Summer-cypress
Lepidium densiflorum	Peppergrass
Malva rotundifolia	Common mallow
Medicago lupulina	Black medick
Medicago sativa	Alfalfa
Melilotus officianalis	Sweet clover
Polygonum convolvulus	Black bindweed
Portulaca oleracea	Common purslane
Potentilla norvegica	Cinquefoil

* Common and scientific names taken from Gray's Manual of Botany (1950).

Appendix A. (Continued).

Rorippa islandica	Yellow cress
Setaria glauca	Pigeon-grass
Setaria viridis	Green foxtail
Solanum rostratum	Buffalo bur
Sonchus sp.	Sow thistle
Taraxacum officinale	Common dandelion
Thlaspi arvense	Field-penny-cress
Trifolium hybridum	Alsike clover

Appendix B. Crop contents of 84 juvenile pheasants analyzed on a percentage-by-volume basis.

Bird	Age (weeks)	Vol. (ml) Animal	Vol. (ml) Plant	Percent Animal
Treated -- Plot 1				
*R-47	3	0.1	Tr	--
*R-19	3	0.0	0.0	--
R-22	3	0.0	0.1	--
R-38	3	Tr	Tr	--
R-42	3	Tr	Tr	--
*R-29	3	0.0	0.0	--
R-23	4	Tr	Tr	--
R-32	4	0.0	0.0	--
R-35	4	0.0	Tr	--
*R-14	5	0.3	0.7	30
R-43	6	0.3	0.7	30
R-55	6	0.2	0.5	29
R-12	7	0.1	1.6	3
R-15	7	0.1	1.0	9
R-39	8	0.4	1.7	19
R-24	9	Tr	0.4	--
R-61	10	Tr	1.2	--
Treated -- Plot 3				
*Y-60	3	0.0	0.0	--
*Y-64	3	Tr	0.0	--
Y- 2	3	Tr	0.0	--
Y- 1	3	Tr	Tr	--
Y-55	3	Tr	Tr	--
Y-46	4	Tr	Tr	--
Y-43	4	Tr	0.0	--
Y-50	5	0.2	0.9	18
Y-58	6	0.5	1.5	25
Y-65	6	Tr	2.0	--

* Birds found dead

Appendix B. (Continued).

Bird	Age (weeks)	Vol. (ml) Animal	Vol. (ml) Plant	Percent Animal
Y-32	7	0.1	2.6	4
Y-49	7	0.1	1.2	8
Y- 9	8	0.2	2.2	8
Y-22	8	0.1	0.7	13
Y-15	9	0.2	0.9	18
Y-34	9	0.1	0.7	13
Y-18	10	Tr	0.2	--
Y-44	10	0.4	1.9	17
Y-23	12	0.8	0.1	89
Y-29	12	Tr	Tr	--

Control -- Plot 2

Bird	Age (weeks)	Vol. (ml) Animal	Vol. (ml) Plant	Percent Animal
*W-39	2	Tr	Tr	--
*W- 6	2	0.0	0.0	--
*W-32	3	0.0	0.0	--
*W-15	3	0.0	0.0	--
W-29	3	0.0	0.0	--
W-24	3	Tr	Tr	--
*W-63	3	Tr	Tr	--
W-21	4	**	**	--
W-47	4	0.2	0.1	67
W- 8	4	0.2	1.2	14
W- 1	5	0.5	0.8	39
W-67	5	0.7	Tr	--
W-25	6	0.2	0.4	34
W-27	6	0.4	0.6	40
W-22	7	0.2	0.1	67
W-51	7	0.2	0.5	40
W-23	8	0.2	4.8	4
W-56	8	0.1	3.6	3
W-31	9	0.1	2.5	4
W-10	9	0.1	0.3	25
W-11	10	01	1.6	6

* Birds found dead
** Crop contents misplaced

Appendix B. (Continued).

Bird	Age (weeks)	Vol. (ml) Animal	Vol. (ml) Plant	Percent Animal
W-16	10	0.1	1.4	7
W-13	11	Tr	1.8	--
W- 1	11	Tr	1.0	--

Control -- Plot 4

*B-18	2	0.0	Tr	--
B-54	3	0.0	0.0	--
B-60	3	Tr	Tr	--
B-59	3	Tr	Tr	--
*B-34	3	0.0	0.0	--
B-48	3	0.0	0.0	--
*B- 9	3	0.0	Tr	--
*B-25	3	0.0	0.0	--
B-65	3	0.0	0.0	--
B-22	4	0.0	0.0	--
B-52	4	0.8	0.2	80
B-14	5	0.4	1.8	18
B-36	5	0.3	1.2	20
B- 6	6	0.4	0.2	67
B-19	6	0.3	1.9	14
B- 4	7	0.1	1.2	8
B-11	7	0.1	0.8	11
B-50	8	0.1	1.1	8
B-21	8	0.1	1.2	8
B- 5	9	0.1	0.4	20
B- 1	9	1.8	0.9	50
B-12	10	Tr	Tr	--
B-10	10	Tr	Tr	--

* Bird found dead